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STING USE IN TWO SPECIES OF *PARABUTHUS* SCORPIONS (BUTHIDAE)

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ABSTRACT. Scorpions sometimes capture and crush prey with their pedipalps and do not use their sting to inject venom. Experiments were conducted to test the hypothesis that sting use is selective, resulting in conservation of venom. Sting use in relation to prey size and activity was studied in two African scorpions, *Parabuthus liosoma* and *P. pallidus*. Restrictive use of the sting was observed in both species. Decreased use of the sting occurred with decreasing size/resistance of the prey. Also, prey were not stung immediately after being seized, but only after resisting capture. The scorpions did not sting non-resistant prey. These results support the notion that sting use depends upon the size, morphology and resistance of the prey as determined during initial interactions with the scorpion.

Scorpions are notorious for their stinging behavior and powerful venoms. Sting use plays an important role in prey capture and defense (Vachon 1953; Cloudsley-Thompson 1958; Stahnke 1966). As yet, there have been no controlled and quantitative studies of sting use, but investigators have suggested a variety of factors that may be correlated with sting use. It appears that scorpions with large, powerful pedipalps seldom use the sting, while species with small, slender pedipalps readily sting their prey (Stahnke 1966; Baerg 1961; McCormick & Polis 1990). Casper (1985) proposed an ontogenetic change in sting use by *Pandinus imperator* Koch. Young individuals stung prey readily, while older and adult individuals were never observed to employ the sting. Similar results were reported by Cushing & Matherne (1980) for *Paruroctonus boreus* Girard. Le Berre (1979) noted decreased sting use with smaller prey in *Buthus occitanus* Amor., and similar observations were reported for other species (Pocock 1893; Vachon 1953; Cloudsley-Thompson 1958; Baerg 1961; Bücherl 1971; Polis 1979).

The purpose of this study is to examine sting use during prey capture by two East African buthids, *Parabuthus liosoma* Hemprich & Ehrenberg and *Parabuthus pallidus* Pocock. Both species used their stings selectively, depending upon the size, morphology and resisting behavior of the prey. Results are discussed in terms of the costs and benefits of venom injection during prey capture.

METHODS

Natural history.—*Parabuthus liosoma* and *P. pallidus* are found in several countries in East Africa (Probst 1973). Adults of the former species are of medium size for scorpions and have a yellow to yellowish-red body, except for part of the cauda and telson which are dark red/brown. They have small, slender pedipalps and a thick, powerful cauda. Similar coloration and morphology is present in *P. pallidus*, but these are slightly smaller and lack the darkened distal part of the cauda. There are no previous reports on the life history or behavior of these species.

Materials.—Individuals of *P. liosoma* and *P. pallidus* were collected in the vicinity of Isiolo, Kenya in May and June, 1988. The animals were found in the same semi-arid area under stones along roadsides, but no more than one scorpion was ever found beneath a single stone. The substrate consisted of compacted sand with occasional grass and bushes.

The scorpions were taken to Norway, where 11 individuals of *P. liosoma* and 12 individuals of *P. pallidus* were used in the experiments. The specimens were of unknown age and ranged in length (pro- and mesosoma) from 18–32 mm ($\bar{x}$ = 25.1 mm, *P. liosoma*) and 13–31 mm ($\bar{x}$ = 21.3 mm, *P. pallidus*).

Specimens were kept individually in terraria (32 × 20 cm), with a substrate of sand and some stones. The temperature was held at 24–30 °C, and the light/dark period was 10:14 hr. Water was provided weekly by misting. Animals were

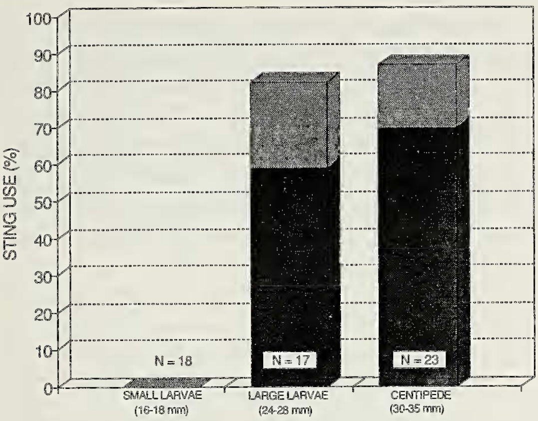

Figure 1.—Sting use against three different prey types in *Parabuthus liosoma*. The whole columns represent total sting use, whereas the dark shaded areas show the percentage successful sting use (see text for further explanations). "N" denotes the number of trials.

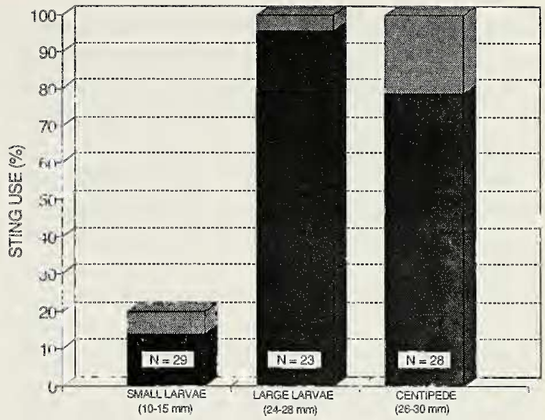

Figure 2.—Sting use against three different prey types in *Parabuthus pallidus*. The whole columns represent total sting use, whereas the dark shaded areas show the percentage successful sting use (see text for further explanations). "N" denotes the number of trials.

not fed except when tested. Only animals active on the surface in the dark period were selected for experiments. This appeared to be a useful indication of hunger, since they usually responded rapidly when prey were offered.

For testing, the scorpions were transferred to an observation terrarium (25 × 25 cm) with a sand floor. They were given one hr for acclimation before prey was introduced. Data on all activities were collected by direct observations under low intensity red light that is apparently not visible to scorpions (Machan 1968). All observations were made during the fall 1988 and spring 1989. Results were tested using a sign test (Lehner 1979).

Experiment 1.—Sting use was compared after presentation of three different types of prey which differed in size and morphology. These were small (10–18 mm) and large (24–32 mm) larvae of *Tenebrio molitor* Linne and a centipede, *Lithobius forficatus* Verhoeff (26–35 mm). Insect larvae and centipedes were seen in the scorpions' habitat in Kenya, and thus are probably natural prey for the two *Parabuthus* species.

After the acclimation period, a live prey was introduced to the test scorpion, and if accepted, observations were continued until ingestion was started. The scorpions were allowed to complete ingestion before they were transferred back to their terrarium. If the prey was not accepted by a scorpion, the test was discontinued, and the animal was returned to its terrarium.

Experiment 2.—Sting use against non-resistant prey was investigated by introducing freshly killed *Tenebrio* larvae (29–35 mm) to the scorpions. The larvae were presented by moving them with forceps on the substrate near the scorpion pedipalps.

RESULTS

Prey were subdued in two ways. In 43.3% of the trials (n = 138), scorpions grasped the prey with one or both pedipalps and then pulled the prey to the chelicera and began ingestion without use of the sting. In the remaining trials, the scorpions used the sting to subdue the prey. In some of the latter trials, scorpions did not succeed in penetrating the prey integument; these scorpions either attempted to sting again or stopped stinging and devoured the prey alive. These cases were recorded as sting use, whereas cases with penetration of the integument were recorded as successful sting use.

Sting use in *P. liosoma*.—In this species, the sting was used significantly less ($P < 0.001$) against small larvae than with the two prey of larger size (Fig. 1). There were no significant differences in sting use against the large larvae and the centipedes. Attempts were made to sting both of the large prey types in about 85% of the trials, and the sting use was successful in 58.8% (larvae) and 69.6% (centipedes) of the trials.

Sting use in *P. pallidus*.—Individuals of this species attempted to sting the small larvae significantly less ($P < 0.005$) than the two large prey types (Fig. 2). Small prey were stung in 20.1% of the trials, whereas the use of the sting against large larvae and centipedes was observed in all trials. Sting use was successful in 13.8% of the trials with small larvae, 95.7% with large larvae and 78.6% with centipedes.

Assessment of prey.—Prey were usually not stung immediately after being seized by the pedipalps. Immediate sting occurred in 14.7% (*P. liosoma*) and 26.3% (*P. pallidus*) of the trials in which the sting was used. In most trials, the sting was used only after the prey struggled and resisted capture. In several trials, the scorpions attempted to subdue the prey with the pedipalps for several minutes before finally using the sting.

Sting use against non-resistant prey.—The scorpions quickly grasped large, dead *Tenebrio* larvae which were moved on the substrate near the pedipalps. Sting use were never observed in any of these cases. This is significantly different from sting use with live prey of the same size (*P. liosoma*, $P < 0.005$, $n = 9$; *P. pallidus*, $P < 0.001$, $n = 13$).

DISCUSSION

The results provide evidence that scorpions restrict use of the sting and thereby conserve venom. This is supported by the observations that they displayed decreasing sting use with decreasing size/resistance of prey (Figs. 1, 2). In most trials when the prey were stung, scorpions did not sting the prey immediately after seizing it (a period of prey assessment occurred before use of the sting). Moreover, no scorpion stung non-resistant prey (dead larvae), even though they were large in size. This also supports the notion that the scorpion evaluates the struggle and resistance activity of the prey before stinging it.

The possibility of restrictive sting use was suggested from earlier observations of several scorpion species (Pocock 1893; Rosin & Shulov 1963; Le Berre 1979; Polis 1979; Cushing & Matherne 1980), but experimental evidence was lacking before the present investigation. Williams (1987) suggested that scorpions more commonly eat their prey alive or crush them by pedipalps than inject venom. A similar pattern of restrictive venom use was reported for some other predators. The ant, *Camponotus maculatus*, uses the venom spray differently for large and small prey (Dejan 1988), and some snakes reportedly vary the quantity of venom used for different prey (Gennaro et al. 1961; Allon & Kochva 1974).

Sting use in *P. liosoma* and *P. pallidus* probably depends upon the size, morphology and resistance of the prey. Large prey (large larvae) and prey with powerful mouthparts (centipedes) were stung frequently by both *Parabuthus* species, whereas small prey (small larvae) and non-resistant prey (dead larvae) were seldom stung. The size and resistance activity of the prey was evaluated by the *Parabuthus* in an assessment period shortly after capture.

A restrictive sting use in *P. liosoma* and *P. pallidus* is probably advantageous because the use of the sting and the following venom renewal is expensive from an energetic point of view. This was not examined, but it is a reasonable hypothesis since the venom contains a mixture of water, salt, proteins and other complex molecules (Simard & Watt 1990).

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